Colias: towards an affordable mobile robot for education in developing countries

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***Abstract*—Educational robotics can play a key role in addressing some of the important challenges faced by higher education in developing countries. One of the major obstacles preventing a wider adoption of initiatives involving educational robotics in these parts of the world is a lack of robot platforms which would be affordable for the local educational institutions. In this paper, we present our inexpensive mobile robot platform Colias and assess its potential for education in developing countries. To this end, we describe hardware and software components of the robot, assess its suitability for education and discuss the missing features which will need to be developed to turn Colias into a fully featured educational platform. The presented robot is one of the key components of our current efforts in popularising educational robotics at African universities.**

I. Introduction

Higher education is considered one of the biggest challenges but also opportunities for developing countries. This is especially true for Sub-Saharan Africa which did not even experience the growth of wealth seen by other developing countries [1]. The challenges faced by African institutions are diverse, ranging from limited economic capabilities to old-fashioned pedagogic methodology failing to engage and teach students effectively. There were some recent efforts made by selected African institutions to improve the quality of teaching and learning by the adoption of educational robotics [2], [3]. Such initiatives follow a belief that robots are an effective means to facilitate more engagement, higher motivation, and the development of practical skill sets, beyond the focus of robotics itself. In our own work [4], we have analysed the effectiveness of robotics as a subject to convey a larger skill set to students, where the positive effect is gained from the "embodiment" and physical presence of robots. This makes the outcomes of practical activities very vivid and immediately accessible, providing a continual formative assessment of learning progress and encouragement to students.

One of the key challenges for adopting educational robots in the curricula of educational institutions in developing countries is related to the availability of affordable robotic platforms. This issue has been recently addressed by a number of initiatives with a prominent example of the "Ultra Affordable Educational Robot" project organised by the African Robotics Network (AFRON) [5]. The scope of the competition is to design and build functional robotic platforms directed at engaging young pupils into STEM subjects and costing an order of magnitude less than commercial robotic products. This competition highlights the current trend in designing modern educational robotics platforms, which need to provide not only functional hardware components but also an easy-to-use programming environment and supplementary teaching material.

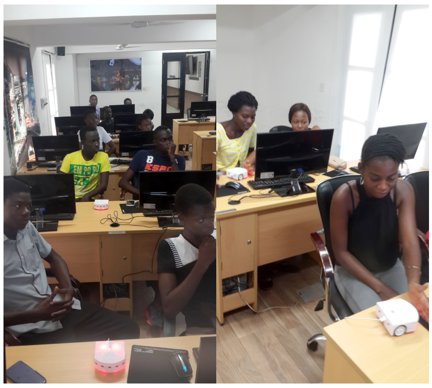

Fig. 1: A pilot study with educational robots at the Department of Computer Science, University of Ghana.

In this context, we are presenting our affordable mobile robotic platform and assess its potential for education at African universities taking into account experience reported by the aforementioned AFRON challenges. Our platform Colias, originates from the swarm robotics research which focuses on developing hardware and software platforms which are by necessity of limited functionality and very low cost. The functionality provided by the hardware of these robots makes them perfect platforms for educational purposes, but so far, the software and supporting materials are not focused on educational use as indicated in our recent survey on affordable mobile robots [6]. We address this issue in our discussions and identify how our platform can be adopted to become more suited for educational purposes.

Colias is one of the key components of our ongoing efforts on bringing educational robotics into curricula of African universities. We specifically focus on enhancing teaching and learning of computer science at undergraduate level to students at the Department of Computer Science, University of Ghana (see Fig. 1). Currently, a three week pilot study using the existing commercial robot platform (i.e. Thymio II) is being undertaken to identify potential educational gains and issues; in future, however our plan is to adopt the developed teaching material for use with Colias and validate the platform potential

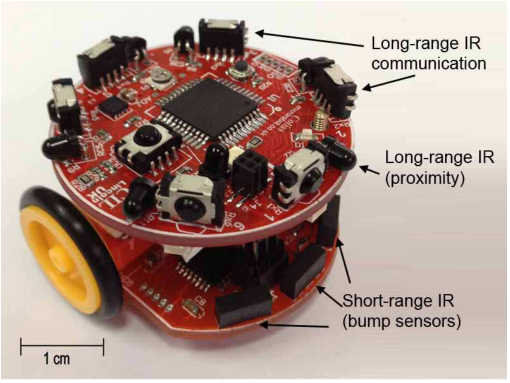

Fig. 2: Colias - our affordable mobile robot.

through in-class activities with Ghanaian students.

II. Colias: affordable robotic platform

Colias is a mobile robotic platform developed at the University of Lincoln, UK for swarm robotic applications [7]. Figure 2 presents our robot and its different components. The robot has two boards upper and lower which have different functions. The upper board is for high-level tasks, such as inter-robot communication and user-programmed scenarios; the lower board is designed for low-level functions such as power management and motion control.

1) On-board Processing: Colias employs two on-board Atmel AVR micro-controllers which work in parallel: μ_1 and μ_2. The parallel processing provides for the fast and reliable control of different functions of the robot. The functions such as power management, obstacle detection and motion control are managed by μ_1. Moreover, μ_2 controls the inter-robot communication and the user-programmed tasks. The communication between the processors is provided by both parallel and serial links (i.e. RS-232, I^{2}C, SPI). The serial links are also used to communicate with the external modules, such as a camera, ultrasonic sensor, external memory and robot-PC link used for software deployment.

2) Actuators: Two micro DC motors employing direct gears and two wheels with a diameter of 2.2 cm actuate Colias with a maximum speed of 35 cm/s. The rotational speed for each motor is controlled individually and each motor consumes up to 150 mA depending on load conditions. The robot uses a differentially-driven configuration resulting in a simple motion control principle. Since the motors are directly supplied by the battery of the robot, any changes in battery level will impact the speed of the robot. The robot does not require a significant torque to move due to its light weight (28 g) and the employed high ratio gearbox.

3) Sensors: The basic configuration of Colias uses only IR proximity sensors to avoid obstacles as well as collisions with other robots, and a light sensor to read the illuminance of the ambient light. The IR sensory system consists of two different types of IR module, namely, short-range sensors which act as bumpers and long-range proximity sensors. A combination of three short-range sensors and an independent processor grants the capacity for a separate process for obstacle detection working in parallel with the rest of the system.

The long-range system (range $\sim$15 cm) is composed of six IR proximity sensors for obstacle and robot detection. The IR sensing system is able to distinguish robots from obstacles. Obstacle detection and distance estimation is based on the reflected IR readings, taking into account reflectivity coefficient, the output power of the emitted IR and the sensitivity of the sensor. In addition, the light sensor is placed at the bottom of the robot and is directly connected to both processors μ_1 and μ_2. Therefore, each controller is able to read the illuminance value of the sensor.

4) Power management: In Colias, the lower board is responsible for managing power consumption as well as the recharging process. The power consumption of the robot with standard motion in a empty enclosed environment and short-range communication (low-power IR emitter) is around 560 mA. However, it can be reduced to about 200 mA when the emitters are turned on only occasionally and the robot moves at a faster speed. A 3.7 V, 600 mAh lithium-polymer battery is used as the main power source, which gives autonomy of around three hours for the robot. More battery power is used by IR emitters and decoders when the emitter is turned on continuously. Therefore, the power consumption can be reduced to at least 50% by using pulse modulation in the IR emitters as well as a short data-packet size. The recharging process of the battery is monitored by internal circuitry and is provided through a USB connector.

III. Platform Assessment & Future Plans

Colias is an affordable mobile robot which at the price of approx. $40 constitutes an attractive educational platform for use in developing countries. The open source hardware and software design (available at [8]) allows the robot to be easily adopted and locally produced keeping the purchasing and maintenance cost low. In near future, Colias will be also available as a commercial product offering an alternative for those institutions without facilities or skills needed for its assembly. Its diverse sensory capabilities, relatively long autonomy (up to 3h), small size and weight make it perfect for teaching subjects such as computer science, electronic engineering but also other science subjects such as physics and maths. There are however certain missing features which would need to be added to turn Colias into a fully featured educational platform and which we describe next.

1) Software Deployment: Straightforward and convenient software deployment is an essential feature which simplifies the ease of use, improves flexibility and general interaction with the platform. Deployment of the robot software is usually implemented by a tethered connection and may in addition require a special programming equipment and software tools. A more favourable wireless connection with PC is not common in affordable platforms, but the benefits arising from such a solution are numerous including interactive debugging, remote control from PC or mobile devices which are essential especially during early stages of education, and interfacing with more complex software components such as ROS which could be used to teach more advanced subjects.

Currently, Colias is using a tethered serial link for software deployment requiring additional programming equipment and software. To simplify this process, a USB-based interface will be developed which only requires adjustments to the firmware (i.e. bootloader) and a few minor modifications to the circuitry without affecting the total price of the robot. To enable wireless communication with the robot, two options are possible. The currently used IR sensors can be also used for short-range wireless communication provided that a PC is equipped with a IR dongle - these are typically inexpensive and quite popular for remote control of A/V systems. An alternative solution would require additional hardware component (e.g. Bluetooth) which are available at approx. \$5.

2) Software Development: An effective and efficient educational platform should come with a dedicated programming environment, simulators and software interfaces. The software libraries provide helpful abstraction of low-level operations so the students can focus more on fundamental issues rather than on specific technical details. In certain subjects like computer science for example, high-level programming language support is crucial so that programming concepts such as variables, loops, subroutines could be introduced. Simulation capabilities can enable teaching of large classes or individual learning outside teaching activities.

The existing software support of Colias is limited to a low-level library simplifying motor control, sensor readings and communication. The programming of the robot in high-level languages such as C is possible through a micro-controller programming environment. Ideally, the robot should have its own dedicated software suite which, if developed from scratch, might be a challenging task. Therefore we will explore the existing open source projects like Aseba, minibloqs, ArduBlock which can be easily adapted to the needs of our robot. One of our current student projects provides an interesting example in this area, where an educational robot Thymio II has been interfaced to the visual programming software Scratch [9]. This work will continue to enable similar functionality to Colias together with development of other software interfaces such as to ROS.

3) Teaching Material: The effective and widespread use of educational robots should be supported by the existence of educational material helping teachers to design subject curricula. This was recently highlighted in the second AFRON robot design challenge [5] which included not only hardware platforms but also accompanying software and supplementary teaching material. These additional features will allow educators in developing countries for preparing lesson material for different study levels without having to change the platforms. Platforms which come equipped with detailed tutorials can support teachers with little or no previous experience in educational robotics which may encourage others to participate in such initiatives to make them sustainable.

Currently, Colias does not come with any teaching material. However, our on-going collaboration with the Department of Computer Science, University of Ghana is looking at development of teaching material with the use of educational robots. Our next steps will involve adopting the developed teaching material for use with Colias and validate the platform potential through in-class activities. High-importance will be dedicated to sustainability of this initiative which in large degree will depend on the availability of such teaching material for new educators.

4) Further hardware modifications: The already attractive price for Colias can be further reduced by removing components specifically designed for swarm applications (e.g. long-range IR sensors). Other hardware modifications might improve the issues around the ease of use and maintenance of Colias which are very important in the context of developing countries. This modifications will include a dedicated charging station which would be especially important if several robots are in use. Also the use of simple enclosure which would assure more sturdy construction and robustness to elements, careless operation, etc. We are also interested in expanding the use of Colias further with additional components such as a platform for distance access to the robot [10] or position tracking which could be used as measuring instrument [11] which would benefit further the platform and its use for education of different subjects.[1]

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